# DESIGN LABORATORY

**(17MEL76)**

**VII Semester**

**[AS PER CHOICE BASED CREDIT SYSTEM (CBCS) SCHEME]**

**DEPARTMENT OF MECHANICAL ENGINEERING**

BAPUJI INSTITUTE OF ENGINEERING AND TECHNOLOGY

DAVANGERE- 577 004

DEPARTMENT OF

# MECHANICAL ENGINEERING

# DESIGN LAB MANUAL

**(17MEL76)**

**VII Semester**

**[AS PER CHOICE BASED CREDIT SYSTEM (CBCS) SCHEME]**

Name : ..................................................

USN : ..................................................

Semester: ............... Batch No.......................


B BASAVARAJ

Faculty Incharge

Suresh U M

Instructor

BAPUJI INSTITUTE OF ENGINEERING AND TECHNOLOGY

DAVANGERE- 577 004

# VISION OF THE INSTITUTE

To be center of excellence recognized nationally and internationally, in distinctive areas of engineering education and research, based on a culture of innovation and invention.

# MISSION OF THE INSTITUTE

BIET contributes to the growth and development of its students by imparting a broad based engineering education and empowering them to be successful in their chosen field by inculcating in them positive approach, leadership qualities and ethical values.

# VISION OF THE DEPARTMENT

The department endeavors to be a center of excellence, to provide quality education leading the students to become professional mechanical engineers with ethics, contributing to the society through research, innovation, entrepreneurial and leadership qualities.

# MISSION OF THE DEPARTMENT

l. To impart quality technical education through effective teachinglearning process leading to development of professional skills and attitude to excel in Mechanical Engineering.

2. To interact with institutes of repute, to enhance academic and research activities.

3. To inculcate creative thinking abilities among students and develop entrepreneurial skills.

4. To imbibe ethical, environmental friendly and moral values amongst students through broad based education

## PROGRAM EDUCATIONAL OBJECTIVES (PEO'S)

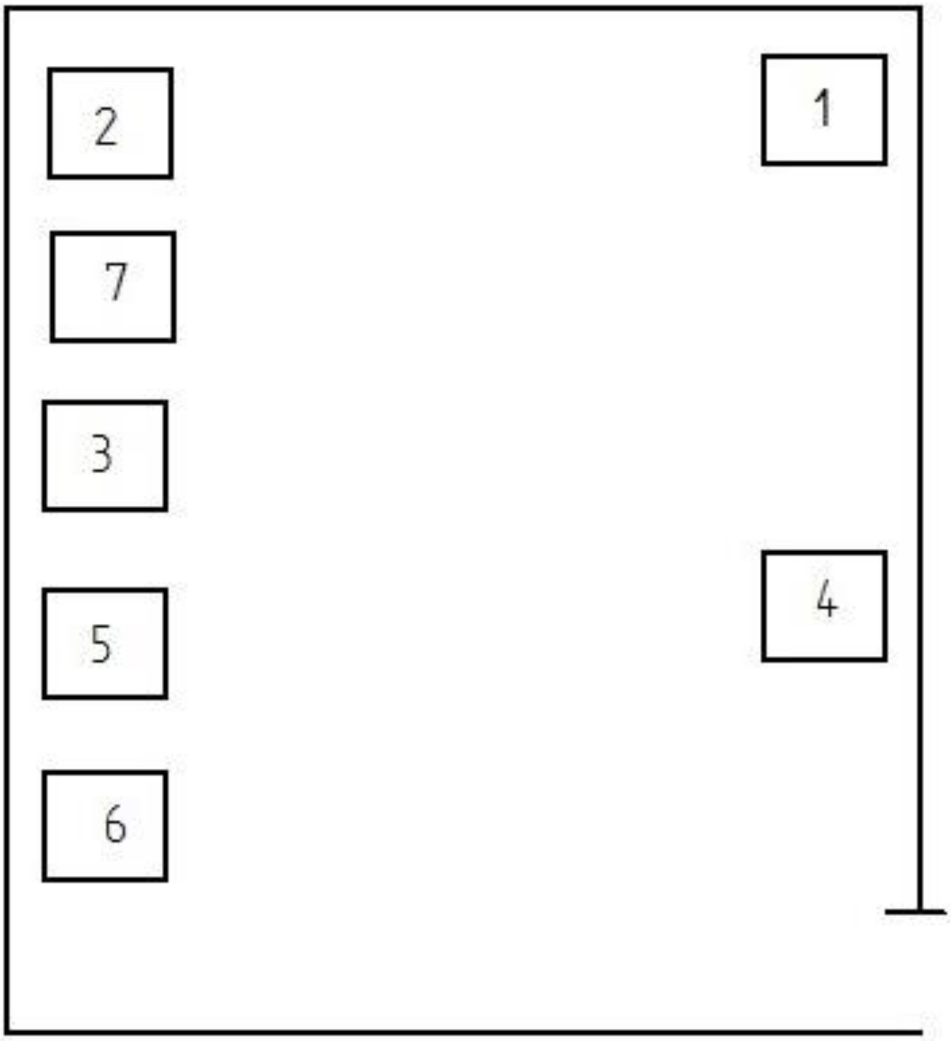
1. Enable to understand mechanical engineering systems those are technically viable, economically feasible and socially acceptable to enhance quality of life.
2. Apply modern tools and techniques to solve problems in mechanical and allied engineering streams.
3. Communicate effectively using innovative tools, to demonstrate leadership and entrepreneurial skills.
4. Be a professional having ethical attitude with multidisciplinary approach to achieve self and organizational goals.
5. Utilize the best academic environment to create opportunity to cultivate lifelong learning skills needed to succeed in profession.

## PROGRAM SPECIFIC OUTCOMES (PSO'S)

PS01:-Apply the acquired knowledge in design, thermal, manufacturing and interdisciplinary areas for solving industry and socially relevant problems.

PS02:-To enhance the abilities of students by imparting knowledge in emerging technologies to make them confident mechanical engineers.

**DESIGN LABORATORY**
**(17MEL76)**




**PART – A**

01. DAMPED TORSIONAL PENDULUM
02. WHIRLING OF SHAFT
03. STATIC & DYNAMIC BALANCING
04. POLARISCOPE

**PART – B**

05. GOVERNOR 18
    a. WATT GOVERNOR 20
    b. PORTER GOVERNOR 22
    c. PROELL GOVERNOR 24
    d. HARTNELL GOVERNOR 26
06. PRINCIPAL STRESS IN COMBINED LOADING USING STRAIN ROSETTES
07. STRESSES DEVELOPED IN CURVED BEAM

## DO's

1. Students must always wear uniform and shoes before entering the lab.
2. Proper code of conduct and ethics must be followed in the lab.
3. Windows and doors to be kept open for proper ventilation and air circulation.
4. Note down the specifications of the experimental setup before performing the experiment.
5. Check for the electrical connections and inform if any discrepancy found to the attention of lecturer/lab instructor.
6. Perform the experiment under the supervision/guidance of a lecturer/lab instructor only.
7. After the observations are noted down switch off the electrical connections.
8. In case of fire use fire extinguisher/throw the sand provided in the lab.
9. In case of any physical injuries or emergencies use first aid box provided.
10. Any unsafe conditions prevailing in the lab can be brought to the notice of the lab in charge.

## DONT's

1. Do not operate any experimental setup to its maximum value.
2. Do not touch/ handle the experimental setups/Test Rigs without their prior knowledge,
3. Never overcrowd the experimental setup/Test Rig, Leave sufficient space for the person to operate the equipment's.
4. Never rest your hands on the equipment or on the display board.

# DESIGN LABORATORY

**[AS PER CHOICE BASED CREDIT SYSTEM (CBCS) SCHEME] SEMESTER – VII**

| Subject Code | 17MEL76 | CIE Marks | 40 |
|---|---|---|---|
| Number of Lecture Hours/ Week | 03 ( 1 Hour Instruction+ 2 Hours Laboratory | SEE Marks | 60 |
| RBT Levels | L1, L2, L3 | Exam Hours | 03 |
| CREDITS - 02 | | | |

**Prerequisites:** Knowledge of Dynamics and Machines and Design of Machine Elements

## COURSE OBJECTIVES:

1. To understand the natural frequency, logarithmic decrement, damping ratio and damping.
2. To understand the balancing of rotating masses.
3. To understand the concept of the critical speed of a rotating shaft.
4. To understand the concept of stress concentration using Photo elasticity.
5. To understand the equilibrium speed, sensitiveness, power and effort of Governor.

## PART-A

01. Determination of natural frequency, logarithmic decrement, damping ratio and damping Co-efficient in a single degree of freedom vibrating systems (longitudinal and torsional)
02. Determination of critical speed of rotating shaft.
03. Balancing of rotating masses.
04. Determination of fringe constant of Photo-elastic material using Circular disk subjected diametric compression, Pure bending specimen (four point bending)
05. Determination of stress concentration using Photo elasticity for simple components like Plate with hole under tension or bending, circular disk with circular hole under compression, 2-D crane hook.

## PART-B

01. Determination of equilibrium speed, sensitiveness, power and effort of Porter/ Proel / Hartnell Governor. (At least one)
02. Determination of pressure distribution in Journal bearing
03. Determination of principle stresses and strain in a member subjected to combined loading using strain rosettes.
04. Determination of stresses in curved beam using strain gauge.
05. Experiments on Gyroscope (Demonstration only)

## COURSE OUTCOMES

**On completion of this subject, students will be able to:**

01. To understand the working principles of machine elements such as Governors, Gyroscopes etc.
02. To identify forces and couples in rotating mechanical system components.
03. To identify vibrations in machine elements and design appropriate damping methods and to determine the critical speed of a rotating shaft.
04. To measure strain in various machine elements using strain gauges.
05. To determine the minimum film thickness, load carrying capacity, frictional torque and pressure distribution of journal bearing.
06. To determine strain induced in a structural member using the principle of photo-elasticity.

## Scheme of Examination:

| | | |
|---|---|---|
| **ONE question from part –A** | **:** | **50 Marks** |
| **ONE question from part –B** | **:** | **30 Marks** |
| **Viva –Voice** | **:** | **20 Marks** |
| **Total** | **:** | **80 Marks** |

**Reference Books:**

[1] "Shigley's Mechanical Engineering Design", Richards G. Budynas and J. Keith Nisbett,

McGraw-Hill Education, 10th Edition, 2015.

[2] "Design of Machine Elements", V.B. Bhandari, TMH publishing company Ltd.

New Delhi, 2nd Edition 2007.

[3] "Theory of Machines", Sadhu Singh, Pearson Education, 2nd Edition, 2007.

[4] "Mechanical Vibrations", G.K. Grover, Nem Chand and Bros, 6th Edition, 1996.

# CONTENTS

# PART - A

Experiment No. 01

## DAMPED TORSIONAL PENDULUM

**Aim:** To study the damped torsional oscillations and determine the damping coefficient. Ct

**Description of set up:**

Figure 6.1 shows the general arrangement for the experiment. It consists of a long elastic shaft gripped at the upper end by the chuck in the bracket. The bracket is clamped to the upper beam of the main frame. A heavy steel flywheel clamped at the lower end of the shaft suspends from the bracket. Damping drum is immersed in the oil which provides damping; oil container can be taken up and down by varying the depth of immersion of damping drum. Depth of immersion can be read from the scale. Recording drum is mounted to the upper face of the flywheel. Paper is to be wrapped around the recording drum. Oscillations are recorded on the paper with help of specially designed piston of dash pot. The piston carries the attachment for fixing the sketching pen.

**Procedure:**

1. With no oil in the container allow the flywheel to oscillate and measure the time for 10 oscillations.
2. Put thin mineral oil (SAE 10 or 20) in the drum and note the depth of immersion
3. Put the sketching pen in its bracket.
4. Allow the flywheel to vibrate.
5. Allow the pen to descend. See that the pen always makes contact with the paper.
6. Note the time for some oscillations by means of stop watch.
7. Determine $X_n$ amplitude at any position and $X_{n+r}$ amplitude after 'r' cycles.

**Tabular column:**

| Sl. No. | Depth of immersion (m) | $X_n$ (m) | $X_{n+1}$ (m) | Logarithmic decrement ‘$\delta$’ | Damping factor ‘$C_t$’ |
|---|---|---|---|---|---|
| 1 | | | | | |
| 2 | | | | | |
| 3 | | | | | |
| 4 | | | | | |

**Calculation:**

1 Find $k_t$ of shaft as follows:

$$k_t = \frac{GI_p}{L} \quad \text{N.m/rad}$$

Where G= modulus of rigidity of shaft = 84 GPa.

$I_p$ = Polar second moment of area of the shaft = $\pi \frac{d^4}{32}$, $m^4$

d = dia of shaft = $4.9 \times 10^{-3}$ m

L = Length of the shaft = 1 m

2. Calculate mass moment of inertia of flywheel using

$$T = 2\pi\sqrt{\frac{J}{k_t}} \quad \text{s}$$

T= periodic time of oscillations in still air.

3. Calculate critical damping coefficient = Cc = $\sqrt{4Jk_t}$

4. Determine logarithmic decrement $\delta$ as follows,

$$\delta = \frac{1}{n} l_n \left( \frac{x_n}{x_{n+1}} \right)$$

5. Find damping ratio $\xi = \frac{C_t}{C_c}$

$$\xi = \frac{\delta}{\sqrt{4\pi^2 + \delta^2}} \quad \text{or} \quad \delta = \frac{2\pi\xi}{\sqrt{1-\xi^2}}$$

6. Find damping factor $C_t = \xi \ C_c$

7. Plot the graph $\xi$ v/s depth of immersion.

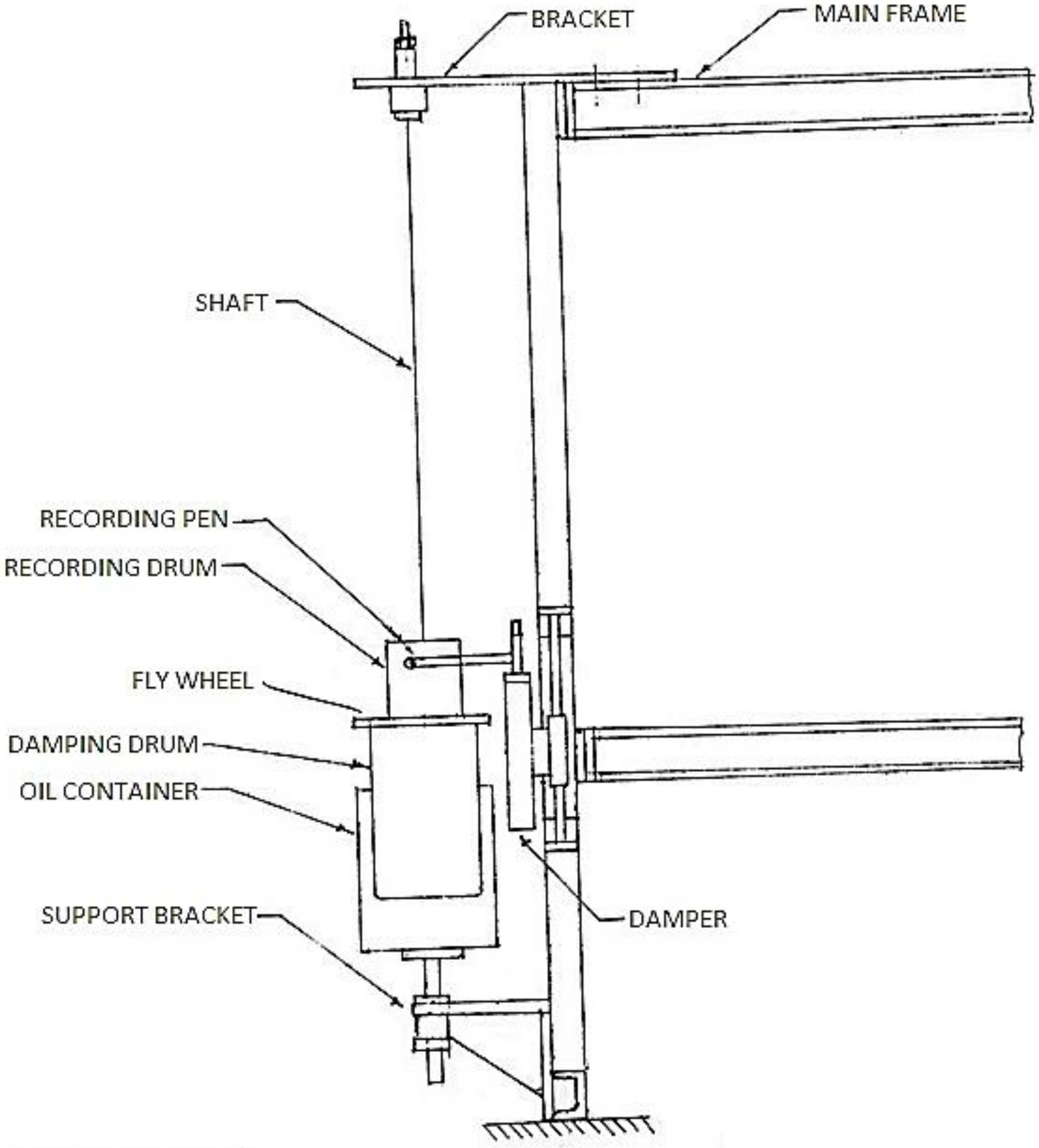

BRACKET
MAIN FRAME
SHAFT
RECORDING PEN
RECORDING DRUM
FLY WHEEL
DAMPING DRUM
OIL CONTAINER
SUPPORT BRACKET
DAMPER

Figure No. 1.1

Experiment No. 02

# WHIRLING OF SHAFT

**Aim:** To Study the Whirling of shaft and to find the critical speeds of shaft and natural frequency of transverse vibration

## Description of the apparatus:

The apparatus consists of a frame to support its driving motor, fixing and sliding blocks, etc. A special design is provided to clear out the effects of bearings of motor spindle from those of testing shafts. The special design features of this equipment are as follows refer Fig.8.1.

(a) KINEMATIC COUPLING (C)

This coupling is specifically designed to eliminate the effect of motor spindle bearings on those of rotating shafts.

(b) BALL BEARING FIXING END (M & N)

These ends fix the shafts while it rotates. The shaft can be replaced within a short time with the help of this unit. The fixing ends provide change of end fixing condition of the rotating shaft as per the requirement.

## Shafts supplied with the equipment

Polished bar steel shafts are supplied with the machine, the dimensions being as under:

| Shaft No | Diameter (mm) (Approx) | Length (mm) (Approx) |
|---|---|---|
| 01 | 5 | 1100 |
| 02 | 6 | 1100 |
| 03 | 8 | 1100 |

## End fixing arrangement

### A) At motor end

The end supporting block may be used with the conditions of fixed end of the rotating shaft. To make the end fixed, both ball bearings support the rotating sleeve. Use Block marked FM (Fixed bearing on Motor side).

**B) Other end**

To provide fixed end and directionally free end, the separate sleeves are provided, each sleeve may be easily fitted in the end supporting block or use the block marked FRT (Free bearing - Tail End)

**Guards D1 & D2**

The guards D1 and D2 (Fig. 8.1) can be fixed at any position on the supporting bar frame E which fits on side supports F. Rotating shafts are to be fitted in blocks in A and B stands.

**Speed control of driving motor**

The driving motor is Tullu make, 250 Volts, AD/DC 1/6 HP 6000 rev/min 50 cps motor and speed control unit is a dimmerstat 240V 2A 50 Hz.

**Measurement of speed**

To measure the speed of the rotating shaft strobometer should be used. A simple tachometer may also be used by removing the bearing cover on the opposite side of shaft extension of the motor, in case strobometer is not available.

**Precaution to be observed during experiment:**

If the revolutions of an unloaded shaft arc gradually increased it will be found that a certain speed will be reached at which violent instability will occur, the shaft deflecting into a single bow and whirling round like a skipping rope. If this speed is maintained the deflection will become so large that the shaft will be fractured, but if this speed is quickly run throu9h the shaft will become so large that the shaft will become straight again and run true until it another higher speed the same phenomenon will occur, the deflection now, however, being in a double bow and so on. Such speeds are called critical speeds of whirling.

It is advisable to increase the speed of shaft rapidly and pass through the critical speeds first rather than observing the 1$^{st}$ critical speed which increases the speed of rotation slowly. In this process there is a possibility that the amplitude of vibration will increase suddenly bringing the failure of the shaft. If, however, the shaft speed is taken to maximum first and then slowly reduced, (thus not allowing time to build-up the amplitude of vibration at resources) higher mode will be observed first and the corresponding speed noted by using a stroboscope and then by reducing the speed further the next mode of lower frequency can be observed without any danger of rise in amplitude as the speed is being decreased and the inertia forces are smaller in comparison with the dangerous amplitudes at recourse or near recourse is avoided.

**Procedure:**

1. One end of the shaft is connected to the motor directly and the other end of the shaft is supported by bearings.
2. A dimmerstat is connected to the motor to vary the speed of the motor.

3. The speed of the motor is varied with the help of dimmerstat such that the shaft exhibits first frequency mode.
4. Note down the speed of the shaft.
5. Again increase the speed of the motor such that the shaft exhibits the second frequency mode.
6. Note down the speed of the shaft.
7. Calculate the natural frequency of given shaft.

**Typical test observation:**

a) Both ends of shaft free (supported); first and second mode of vibration can be observed on shafts with 5 mm dia and 6 mm dia.
b) One end of shaft fixed and the other free; first and second mode of vibration can be observed on shaft with 5 mm dia.
c) Both ends of shaft fixed; second mode of vibration cannot be observed on any of the shafts as the speeds are very high and hence beyond the range of the apparatus.

There is a difference between theoretical speed of whirl and actual speed observed, due to the following reasons:

1) The end conditions are not as exact as assumed in theory.

2) Pressure of damping at the end bearing.

3) Assumption made in theoretical predictions.

4) Lack of knowledge of exact properties of the shaft material.

**Tabular column:**

| Sl. No. | End condition | Mode of whirl | Speed (rpm) | Frequency $f_{exp}$ (Hz) | Frequency $f_{the}$ (Hz) |
|---|---|---|---|---|---|
| 1 | Supported-fixed | First mode | | | |
| 2 | | Second mode | | | |
| 3 | Supported-supported | First mode | | | |
| 4 | | Second mode | | | |

**Calculation:**

The frequency of vibration for the various modes is given by the equation,

$$f = k\sqrt{\frac{EIg}{WL^4}} \text{ Hz}$$

L = Length of the shaft, m

E = Young's Modulus, Pa

I = Second moment of area of the shaft, $m^4$

W = Weight of the shaft per unit length, N/m

g = Acceleration due to gravity = 9.81 $m/s^2$

The various values for K are given below:

| End condition | Value of k | |
|---|---|---|
| | 1st mode | 2nd mode |
| Fixed, Supported | 2.45 | 7.96 |
| Supported, Supported | 1.57 | 6.30 |

$$I = \frac{\pi d^4}{32}$$

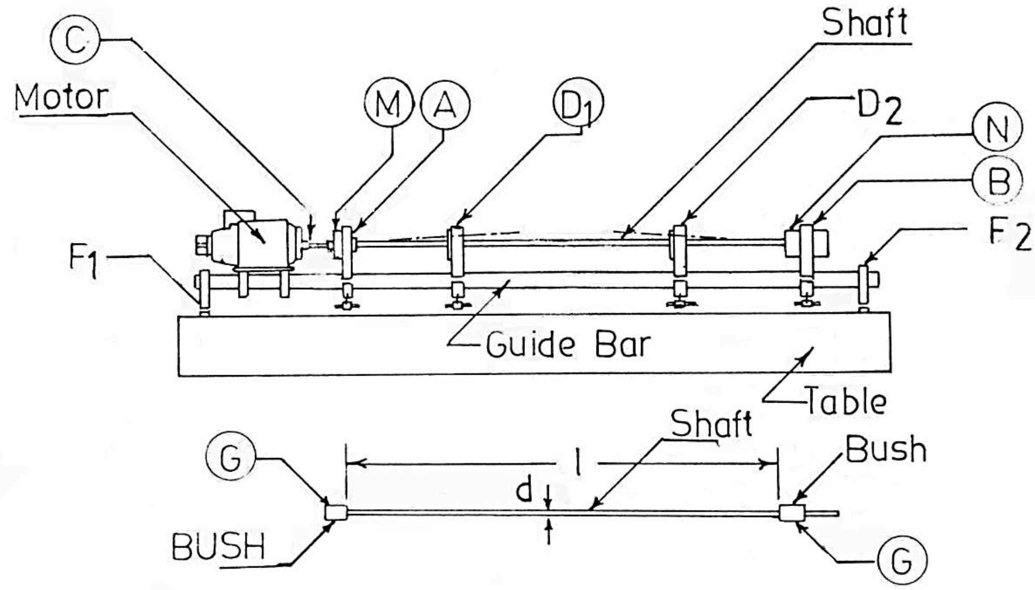
$$W = \frac{\pi}{4} d^2 \times 1.0 \times 7800 \times 9.81$$

| Shaft diameter (mm) | I ($m^4$) | Weight / m length, W (N/m) |
|---|---|---|
| 5.0 | $6.135 \times 10^{-11}$ | 1.502 |
| 6.4 | $1.647 \times 10^{-10}$ | 2.461 |
| 8.0 | $3.974 \times 10^{-9}$ | 3.750 |

Natural frequency $\omega_n = \frac{2\pi N}{60}$ rad/s

Experimental value of frequency $f_{exp} = \frac{\omega_n}{2\pi}$ Hz

# WHIRLING OF SHAFTS APPARATUS




C - Flexible shaft

M-N - Ball Bearing Fixing Ends

$D_1$-$D_2$ - Guards

A-B - Stand For Fixing M & N

M – M.M —— Motor side free block

FM —— Motor side fix block

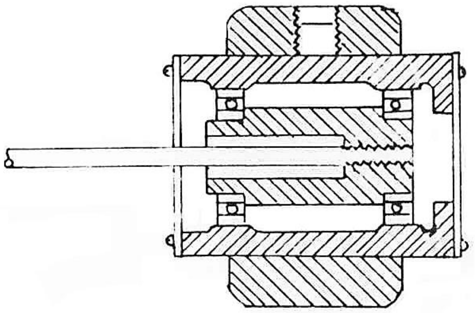
N – MT —— Tail side free block

FT —— Tail side fix block

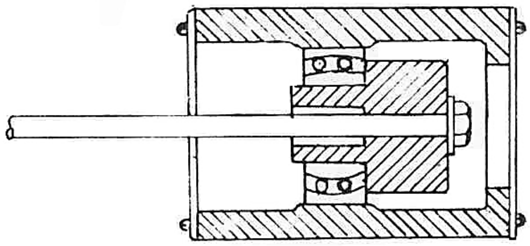
$F_1$-$F_2$ - Side Supports

G - Bushes At The Shaft Ends

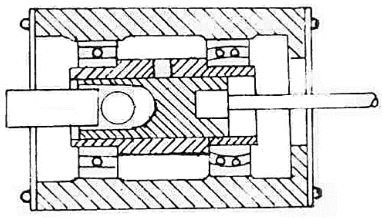
Figure No. 2.1



Fixed end fig.2



Free end fig. 3



Kinematic coupling fig. 4.

POSSIBLE EXPERIMENTS
WITH ELASTIC RODS.

| EXPT NO. | END FIXINGS | MODE OF WHIRL |
|---|---|---|
| 1 | Supported fixed | 1st Mode |
| 2 | Supported fixed | 2nd. Mode |
| 3 | Supported Supported | 1st. Mode |
| 4 | Supported Supported | 2nd. Mode |

Experiment No. 03

## STATIC AND DYNAMIC BALANCING

**Aim:** To determine the position of counter balancing weights in the rotating mass system.

**Description:**

The apparatus basically consists of a steel shaft mounted in ball bearings in a stiff rectangular main frame. As set of four blocks of different weights are provided and may be clamped in any position on the shaft; they can also be easily detached from the shaft. A disc carrying a circular protractor scale is fitted to one side of the rectangular frame, shaft carries a disc and rim of this disc is grooved to take a light string provided with two cylindrical metal containers of exactly the same weight.

A scale is fitted to the lower member of the main frame and when used in conjunction with the circular protractor scale, allows the exact longitudinal and angular position of each adjustable block to be determined. The shaft is driven by a 230 volts single phase 50 cycles electric motor, mounted under the main frame, through a round section rubber belt.

For static Balancing of individual weights the main frame is rigidly attached to support frame by nut and bolts and in this position the motor driving belt is removed.

For dynamic balancing of the rotating mass system the main frame is suspended from the support frame by two short links such that the main frame and the supporting frame are in the same plane.

**Procedure:**

**Static Balancing:**

For finding out 'mr' during static balancing proceed as follows: -

1. Remove the belt and attach the main frame to support frame rigidly and right angles as shown in figure.
2. Screw the Combined hook to the pulley with groove (thus pulley is different than the belt pulley)
3. Attach the cord-ends of the pans to the above hook.
4. Attach block No.1 to the shaft at any convenient position.
5. Put steel balls in one of the pans to make the block horizontal.
6. Number of 'N' balls gives the 'mr' value of block 1.
7. Repeat the procedure for other three blocks.

**Dynamic Balancing:**

It is necessary to level the machine before the experiment. Using the values of 'mr' obtained as above, if the angular positions and planes of rotation of two or possibly three of the blocks are known, the student can calculate the position of the other block/blocks for the balance of the complete system. From the calculations, the student finally clamps all the blocks into the shaft in their appropriate positions. Replace the motor belt, transfer the main frame to its hanging position and then by running the motor up to certain speed to verify the calculations are correct and the blocks are perfectly balanced. If, by chance the student goes wrong in his calculations, then the fact that the blocks are not dynamically balanced is at once revealed by the vibration of the suspended assembly.

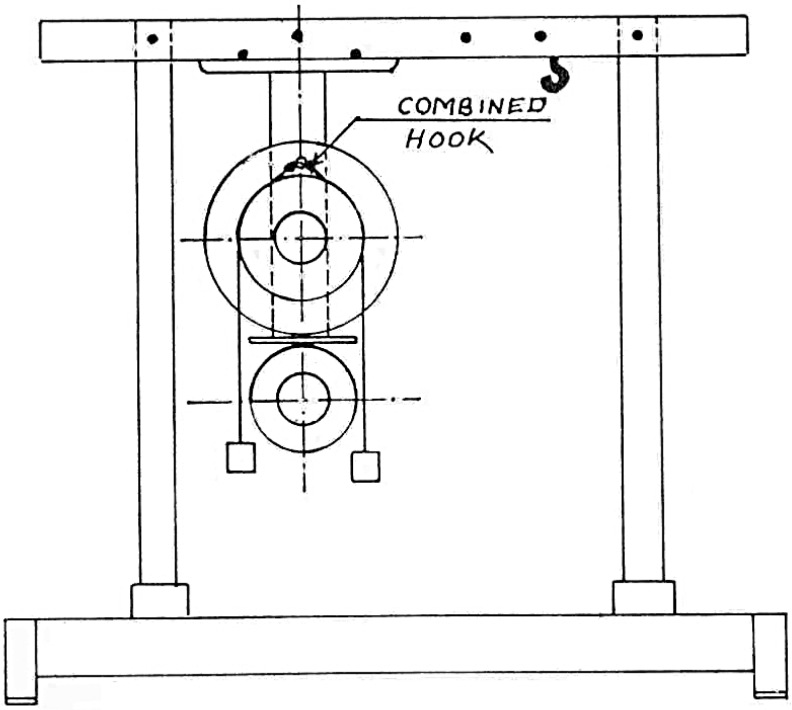
1. Determine the weight of each block.
2. A force polygon is to be drawn to determine the angular positions of block-3 and 4.
3. To calculate the longitudinal positions of block-3 and 4, let the distance from block-1 be m and l respectively.
4. Plot the couple polygon and determine the unknown distances.
5. After knowing the distances and the angular positions, fix the blocks to those positions and check whether the shaft vibrates or not by running it.

To statically and dynamically balance a four plane rotating mass system, block-2 is to be positioned at $60^0$ anticlockwise and 150mm along the shaft from block-1. Determine the angular and longitudinal positions of block -3 and 4 for perfect balance.

**Tabular column:**

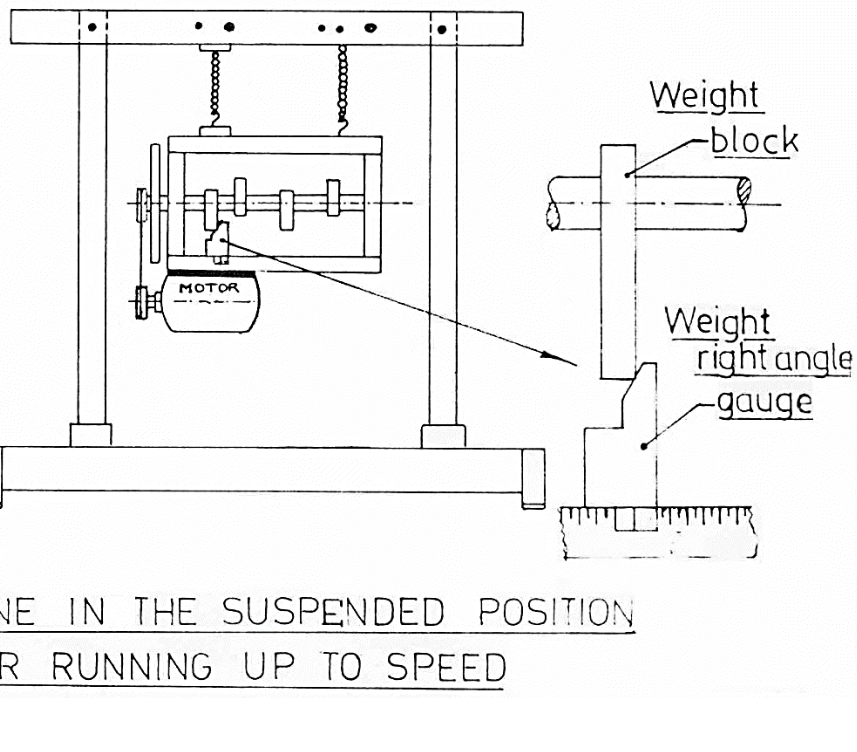
| Block No. | Force polygon, 'mr' in gm-mm | Distance from the reference plane, '$\ell$' in mm | Couple polygon, 'mr$\ell$' in gm $mm^2$ |
|---|---|---|---|
| 1 | | | |
| 2 | | | |
| 3 | | | |
| 4 | | | |

# STATIC BALANCING APPARATUS

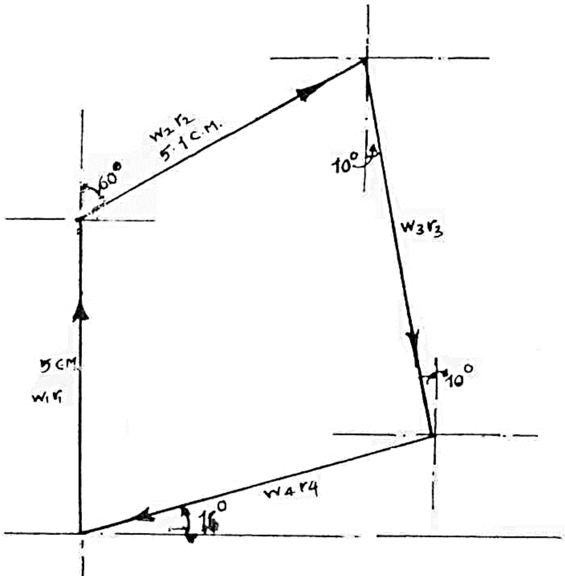



MACHINE RIGIDLY FIXED IN POSITION
FOR DETERMINATION OF mr

## DYNAMIC BALANCING APPARATUS

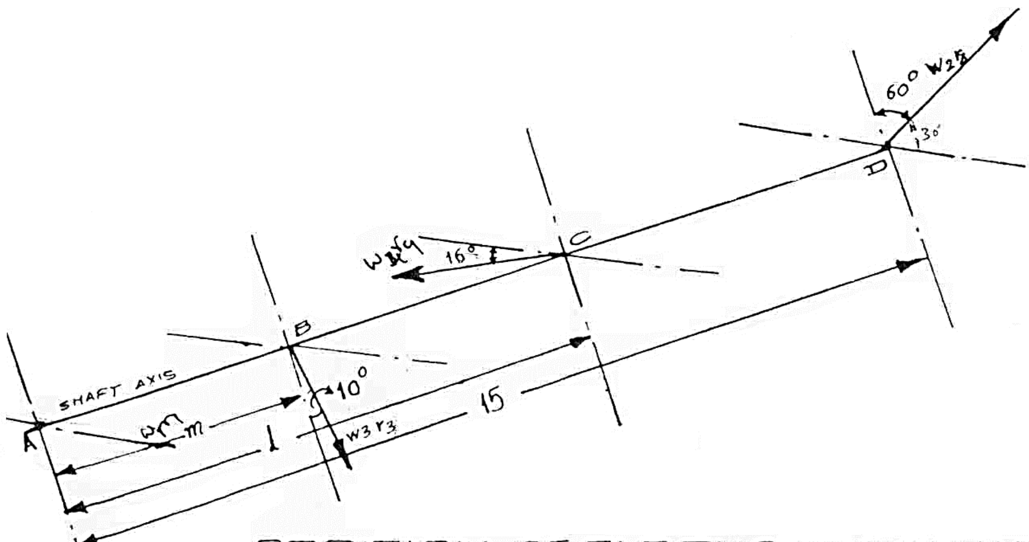



MACHINE IN THE SUSPENDED POSITION
FOR RUNNING UP TO SPEED




## DYNAMIC BALANCING APPARATUS

POLYGON OF FORCES




POSITION OF BLOCKS ON THE SHAFT

Experiment No. 04

## POLARISCOPE

**Aim:** To find out the stresses developed in models made of Photo elastic material.

**Introduction:**

The photo elastic polariscope is an instrument used to find out the stress developed in many complicated machine and structural parts by making use of models made of photo elastic material. The polariscope basically consists of polarizer, two quarter wave plates, and an analyzer and light source. The light source is diffused system. For observations in circularly polarized light two quarter wave plates are introduced, between the polarizers on each side of the model. The axes of the Polaroid's may be either crossed or parallel and so also may those of the quarter wave plates. The model is placed in the field of circularly polarized light between the quarter wave plates.

The arrangement shown, fig 'A', in which both the polaroid's and the quarter wave plates are crossed is known as circular polarisocpe. The plane polarized wave emerging from the polarizer is converted by the first quarter wave plate into a counter clockwise circularly polarised wave. The second quarter wave plate reconverts this into a plane polarised wave vibrating in the vertical plane identical with that emerging from the polariser, except for some loss of intensity. With the axis of analyser horizontal the light is therefore extinguished. Thus when a model is inserted in this polariscope it appears against a dark background. If the analyser is rotated through 90 degree from the position shown so that it is then parallel to the polariser, the emerging from second quarter wave plate is transmitted and the back ground will be bright.

**Loading method:**

It is obvious that a suitable straining machine is essential for photo-elastic studies. The problems in a photo-elastic laboratory are different from the problems of material testing laboratory and the equipment must also be different.

A simple universal testing machine can produce tension, compression, bending and torsion. It is provided with a horizontal and vertical motion for the model under load, and the whole machine can easily be adjusted to remove space effect. It is very sensitive & has a range from a few kilograms to a ton. It can easily accommodate models cut from a whole bakelite plate. It has been used not only to apply small loads for photo-elastic stress pattern but also to test specimen to destruction. The bars are equipped with rows of circular holes to facilitate the application of tensile and compressive loads and bending loads. Tensile loads are applied through devices which are suspended from pins passing through the holes in the bars. Compressions are applied through pins resting in the grooves.

**Calibration of fringe pattern:**

The relative retardation can be expressed either in the form of fringe order or in terms of wave lengths. If 'N' is the number of wave lengths of relative retardation.

$$\sigma_1 - \sigma_2 = fN$$

or

$$\sigma_1 - \sigma_2 = \frac{F}{d} N$$

Where, f = model fringe constant

F = material fringe constant

The model fringe constant is defined as the value of necessary to cause of relative retardation of 1 in the model of given thickness d. the material fringe constant F is the value of $\sigma_1$ - $\sigma_2$ to cause a relative retardation in the f unit thickness. The method to determine either f or F for given model material is called calibration method.

<u>**Circular disc**</u>

**Observation:**

Diameter of the specimen, D = _ _ _ _ mm

Thickness of the specimen, h = _ _ _ _ mm

**Tabular column:**

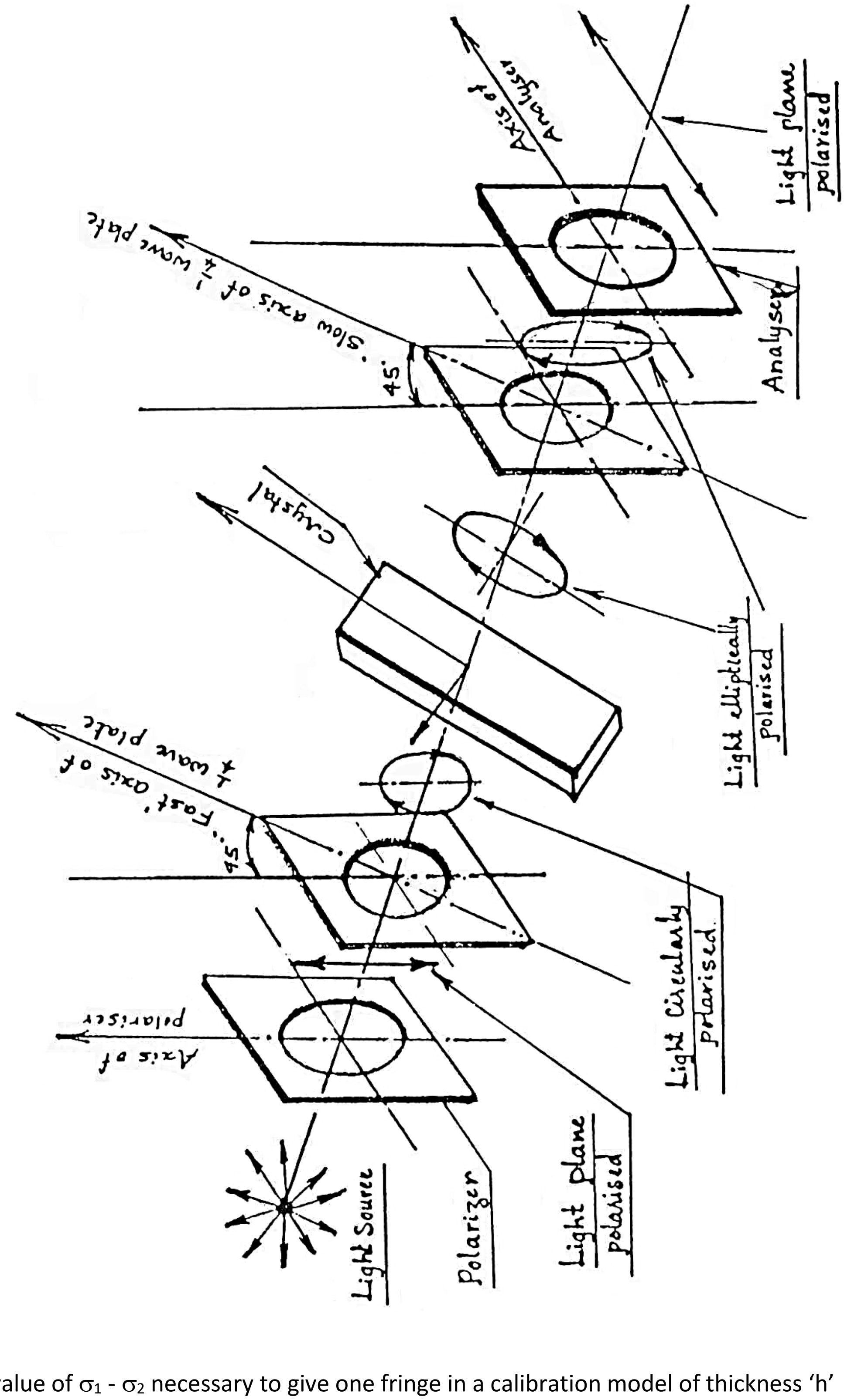
| Sl. No. | Load applied (N) | No. of fringes |
|---|---|---|
| 1 | | |
| 2 | | |
| 3 | | |
| 4 | | |

A circular disc under diametric compression is also used as a calibration specimen. A circular disc can be easily machined and loading is simpler.

The stress distribution along horizontal diameter is given by,

$$\sigma_1 - \sigma_2 = \frac{8P}{\pi h D}$$

The formation of fringes at the centre can easily be observed & a curve can be plotted and the average load $P_1$ to obtain one fringe at the centre determined.




Hence value of $\sigma_1$ - $\sigma_2$ necessary to give one fringe in a calibration model of thickness 'h'

$$f = \frac{8P_1}{\pi h D}$$

Therefore material fringe value, $f = \dfrac{8P_1}{\pi h D}$

Where $P_1$ is load per fringe, obtained from the slope in graph drawn load v/s no. of fringe

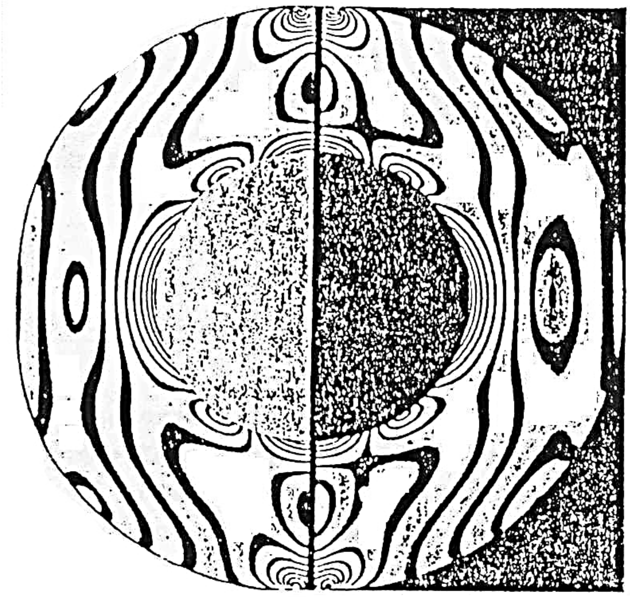


Fig. Isochromatics under bright and dark fields

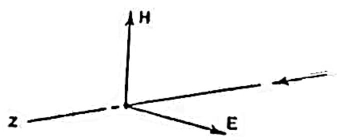



Fig. B Electric and magnetic vectors

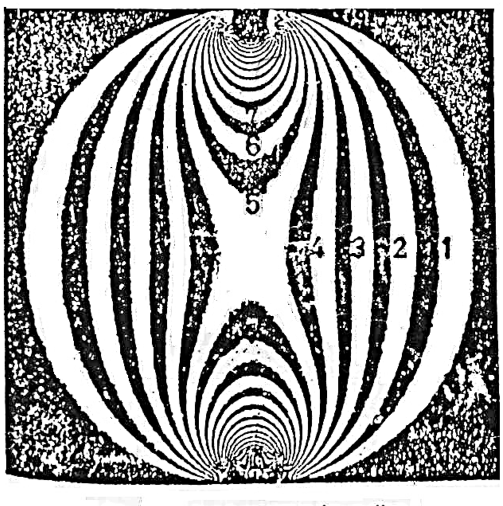



Fig. Isochromatics for a disc

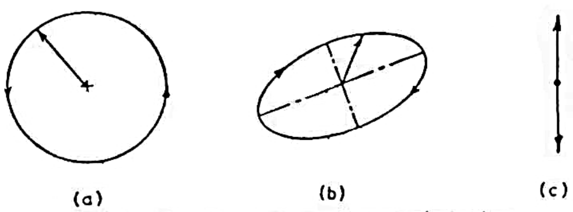



Fig. D Circular, elliptic and linear polarizations

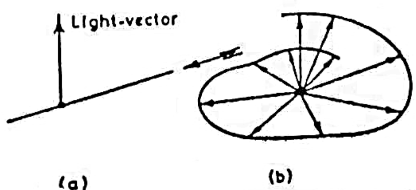



Fig. C Ordinary light—random vibratory motion

# PART - B

Experiment No. 05

## GOVERNOR

**Aim:** To study the operating characteristics of a) Watt, b) Porter, c) Proell and d) Hartnell type governors by plotting the graph of Force v/s radius and Speed v/s Sleeve displacement

**Description of the set-up:**

Drive: DC Motor, ¼ H.P Speed: 1500 rev/min

Speed variation arrangement is provided. Separate linkages for governor arrangements mentioned above are provided using same motor and base. Speed measurement is to be done by hand tachometer, (Not provided with unit) sleeve displacement is to be noted on scale provided. Variable speed control unit is provided with the apparatus. Following experiments can be conducted on the Gravity controlled governor apparatus i.e. for Watt governor, Porter governor and proell governor and also on spring loaded governor.

**Experimental procedure:**

The governor mechanism under test is fitted with the chosen rotating weights and spring, where applicable, and inserted in to the drive unit. The following simple procedure may then be followed.

The control unit is switched on and the speed control slowly rotated, increasing the governor speed until the centre sleeve rises off the lower stop and aligns with the first division on the graduated scale. The sleeve position and speed are then recorded. Speed may be determined using a hand tachometer on the spindle. The governor speed is then increased in steps to give suitable sleeve movements and readings repeated at each stage throughout the range of sleeve movement possible.

The result may be plotted as curves of speed against sleeve position. Further tests are carried out changing the value of variable at a time to produce a family of curves.

Drive unit- DC motor 0-1500 rev/min provides between 0 to 750 rev/min at governor main shaft.

**Procedure:**

1. Arrange the set up as a Watt, Porter, Proell and Hartnell governor. This can be done by removing the upper sleeve on the vertical spindle of the governor and using proper linkages provided.
2. Make proper connections of the motor.
3. Increase the motor speed slowly and gradually.
4. Note the speed by tachometer and sleeve displacement on the scale provided.
5. Plot the graph of speed v/s sleeve displacement for watt, porter, proell and hartnell governor.
6. Plot the graph of speed v/s governor height for watt governor.
7. Plot the governor characteristic after doing the necessary calculations

## a. WATT GOVERNOR

**Observation:**

a) Length of each link $l$ = ______, mm

b) Initial height of governor $h_0$ = ______, mm

c) Initial radius of rotation $r_o$ = ______, mm

d) Mass of each ball m = 0.4 kg

**Tabular column:**

| Sl. No. | Speed ‘N’ (rpm) | Sleeve displacement ‘x’ (mm) | Height, h in mm | Radius of rotation ‘r’ in mm | Force ‘F’ |
|---|---|---|---|---|---|
| 1 | | | | | |
| 2 | | | | | |
| 3 | | | | | |
| 4 | | | | | |
| 5 | | | | | |

Go on increasing the speed gradually and take the readings of speed of rotation ‘N' and corresponding sleeve displacement 'x', radius of rotation ‘r’ at any position could be found as follows:

**Calculation:**

i) Height $h = h_0 - \frac{x}{2}$

ii) Find ‘α’ using $\cos\alpha = \frac{h}{l}$

iii) Radius $r = 50 + l\sin\alpha$

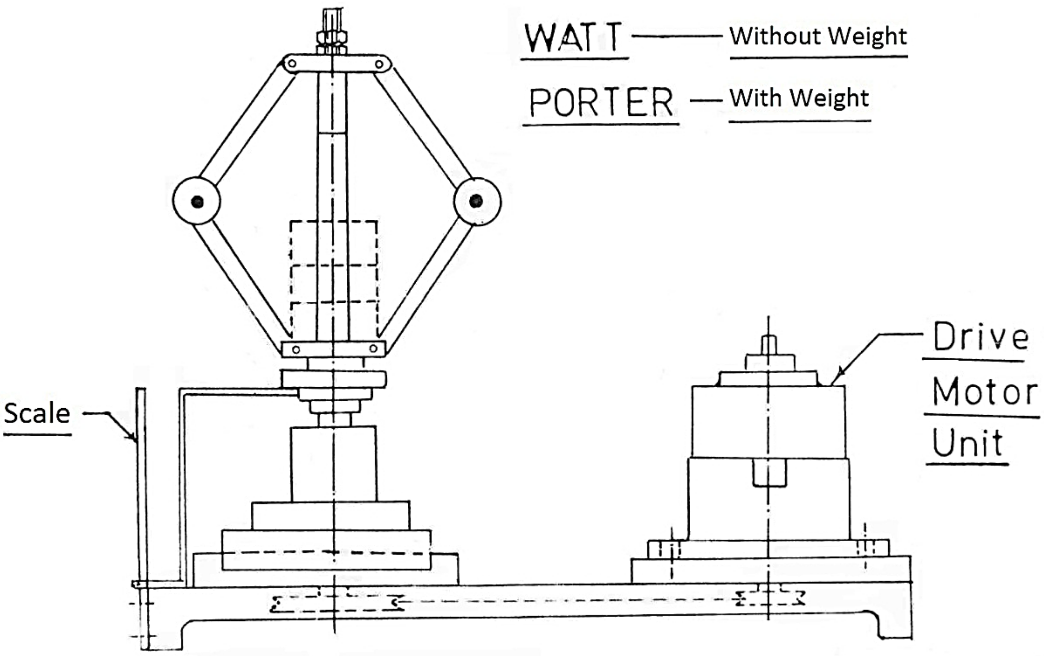
iv) Force $F = m\omega^2 r$

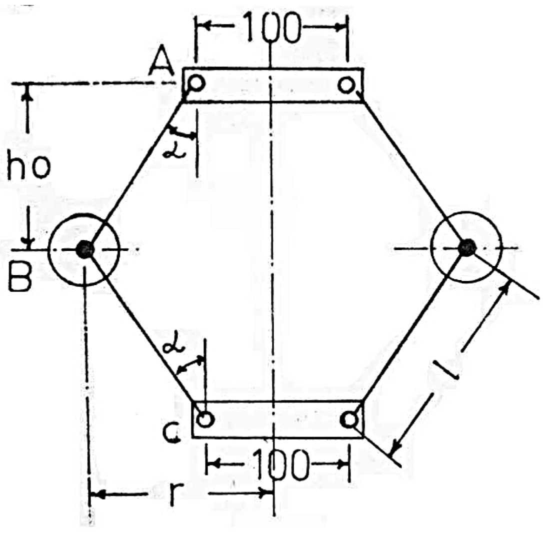
Following graphs may then be plotted to study governor characteristics

i) Force v/s radius of rotation

ii) Speed v/s displacement

# WATT & PORTER GOVERNOR




WATT GOVERNOR

**b. PORTER GOVERNOR**

**Observation:**

a) Length of each link $l$ = ______, mm

b) Initial height of governor $h_0$ = ______, mm

c) Initial radius of rotation $r_o$ = ______, mm

d) Mass of sleeve. = ______, kg

e) Mass of each ball m = 0.4 kg

**Tabular column:**

| Sl. No. | Speed 'N' (rpm) | Sleeve displacement 'x' (mm) | Height, h in mm | Radius of rotation 'r' in mm | Force 'F' |
|---|---|---|---|---|---|
| 1 | | | | | |
| 2 | | | | | |
| 3 | | | | | |
| 4 | | | | | |
| 5 | | | | | |

Go on increasing the speed gradually and take the readings of speed of rotation 'N' and corresponding sleeve displacement 'x', radius of rotation 'r' at any position could be found as follows:

**Calculation:**

i) Height $h = h_0 - \frac{x}{2}$

ii) Find 'α' using $\cos\alpha = \frac{h}{l}$

iii) Radius $r = 50 + l\sin\alpha$

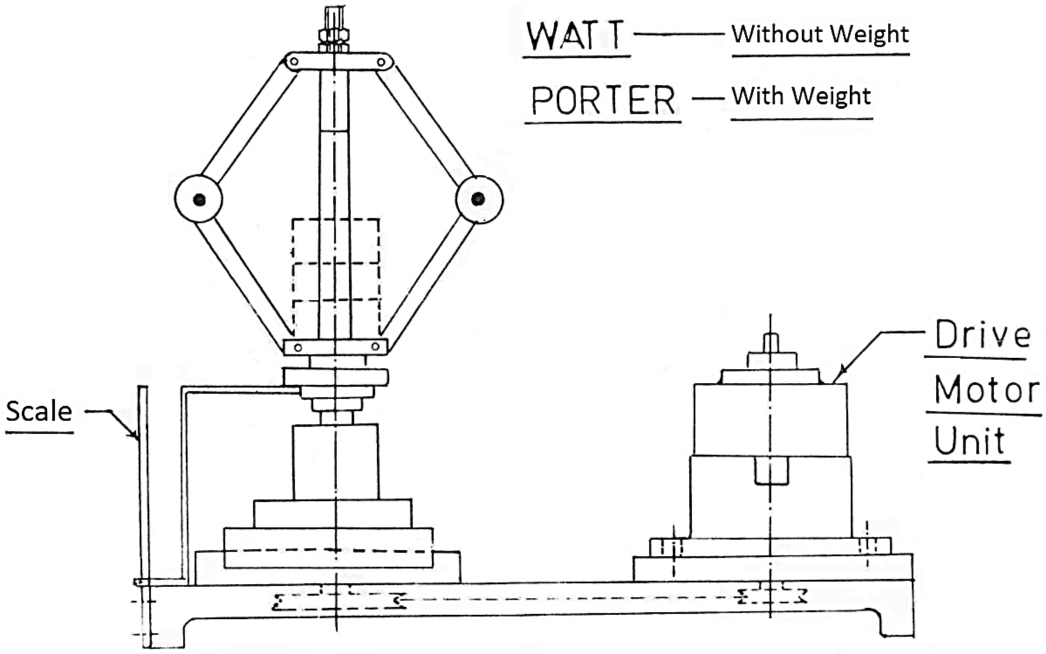
iv) Force $F = m\omega^2 r$

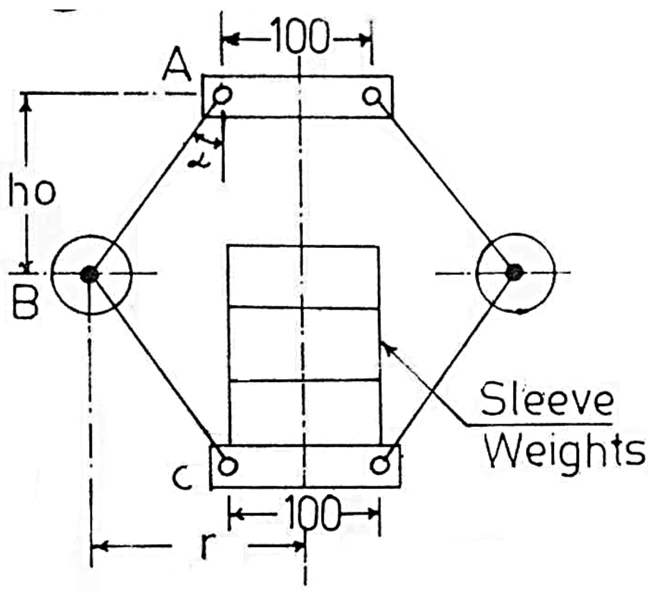
Following graphs may then be plotted to study governor characteristics

i) Force v/s radius of rotation

ii) Speed v/s displacement

# WATT & PORTER GOVERNOR




PORTER GOVERNOR

**c. PROELL GOVERNOR**

In the proell governor, with the use of fly weights (Forming full ball) the governor becomes highly sensitive.

Under these conditions large sleeve displacement is observed for very small change in speed.

In order to make it stable, it is necessary to carry out the experiments by using half ball flyweight on each side.

**Observation:**

a) Length of each link, $l$ = ______, mm

b) Initial height of governor, $h_0$ = ______, mm

c) Initial radius of rotation, $r_o$ = ______, mm

d) Mass of sleeve. = ______, kg

e) Mass of each ball m = 0.4 kg

f) Extension of length BG = ______, mm

**Tabular column:**

| Sl. No. | Speed 'N' (rpm) | Sleeve displacement 'x' (mm) | Height, h in mm | Radius of rotation 'r' in mm | Force 'F' |
|---|---|---|---|---|---|
| 1 | | | | | |
| 2 | | | | | |
| 3 | | | | | |
| 4 | | | | | |
| 5 | | | | | |

Go on increasing the speed gradually and take the readings of speed of rotation 'N' and corresponding sleeve displacement, 'x' radius of rotation 'r' at any position could be found as follows:

**Calculation:**

i) Height $$h = h_0 - \frac{x}{2}$$

ii) Find 'α' using $$\cos\alpha = \frac{h}{l}$$

iii) Radius $$r = 50 + l\sin\alpha + BG\sin\beta$$ Where $\beta_1 = \alpha_1 - \alpha_0$

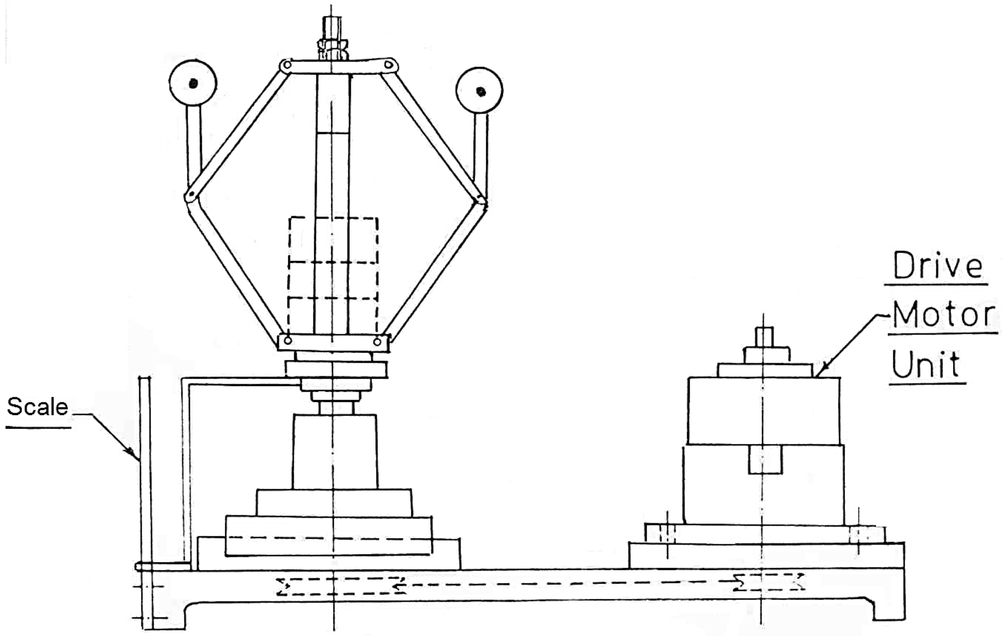
iv) Force $$F = m\omega^2 r$$

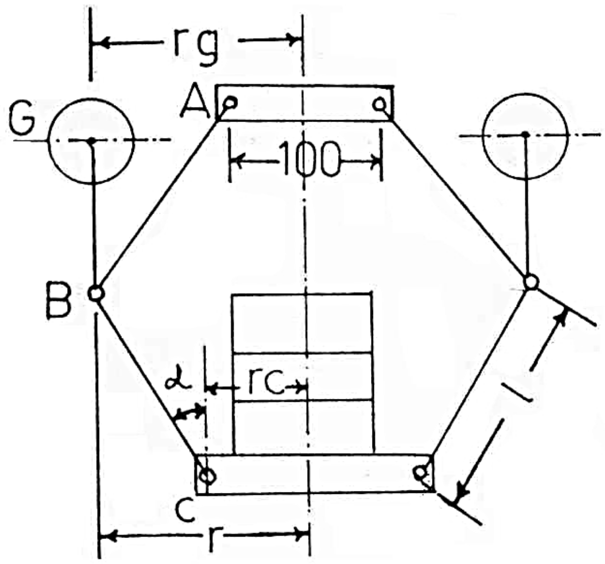
Following graphs may then be plotted to study governor characteristics

i) Force v/s radius of rotation

ii) Speed v/s displacement

# PROELL GOVERNOR ARRANGEMENT




PROELL GOVERNOR

**d. HARTNELL GOVERNOR**

**Observation:**

a) Length a = _____, mm

b) Length b = _____, mm

c) Free height of spring = _____, mm

d) Initial radius of rotation $r_o$ = _____, mm

e) Mass of each ball m = 0.4 kg

**Tabular column:**

| Sl. No. | Speed 'N' in (rpm) | Sleeve displacement 'x' (mm) | Radius of rotation 'r' mm | Force 'F' |
|---|---|---|---|---|
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |
| 4 | | | | |
| 5 | | | | |

Go on increasing the speed gradually and take the readings of speed of rotation 'N' and corresponding sleeve displacement 'x', radius of rotation 'r' at any position could be found as follows:

**Calculation:**

Radius $$r = r_0 + x\left[\frac{a}{b}\right]$$

Force $$F = m\omega^2 r$$

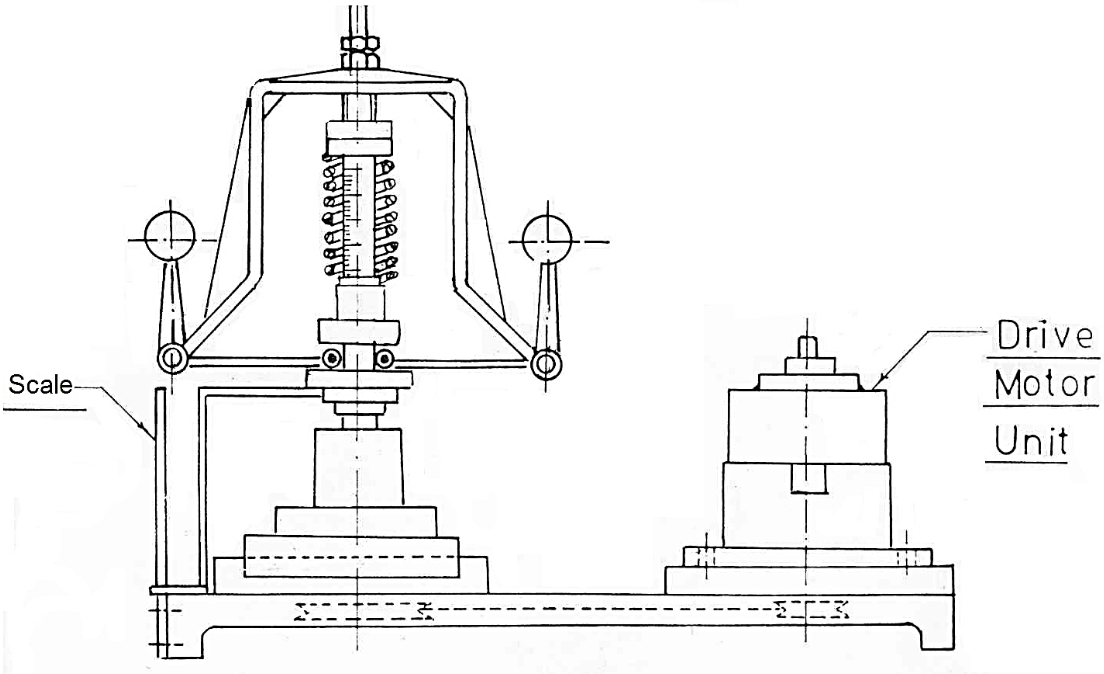
Following graphs may then be plotted to study governor characteristics

i) Force v/s radius of rotation

ii) Speed v/s sleeve displacement

# SPRING CONTROLLED HARTNELL GOVERNOR

## ARRENGEMENT



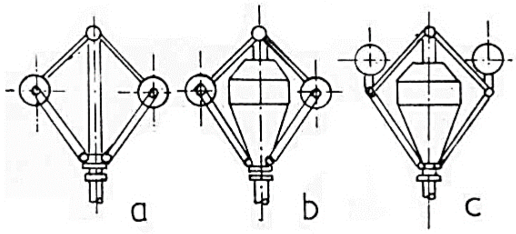



FIG. NO. 1

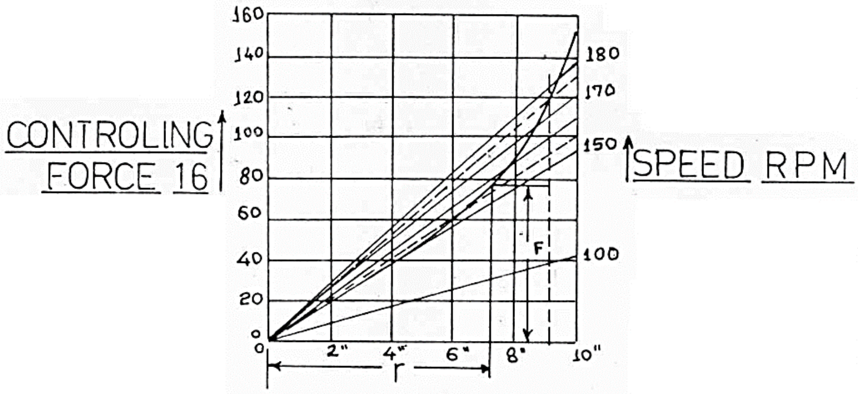



FIG. NO. 2

UNIVERSAL GOVERNOR HARTNELL TYPE

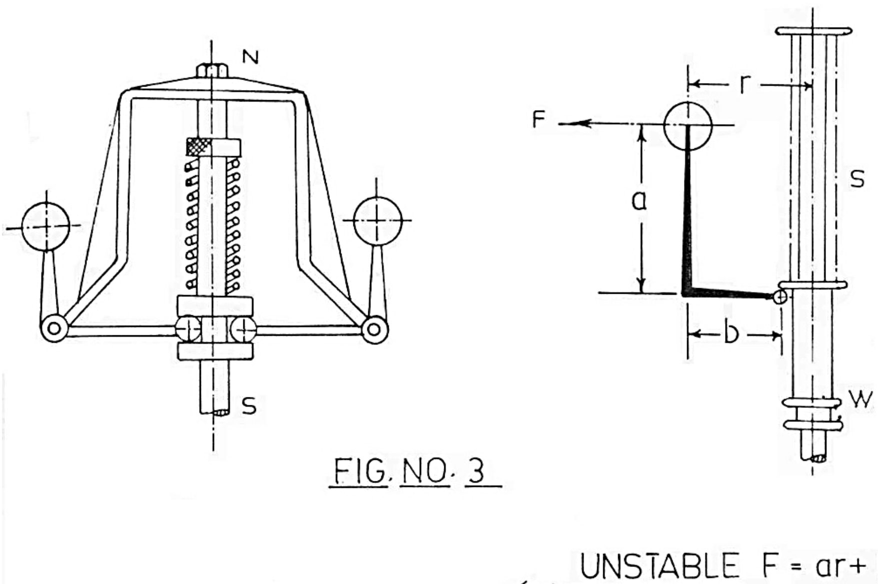



FIG. NO. 3

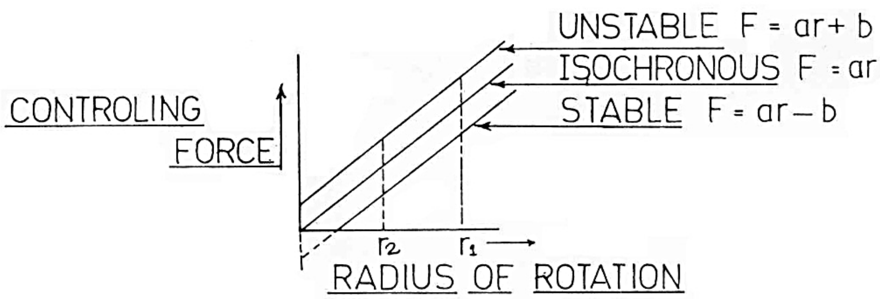



FIG. NO. 4

Experiment No. 06

## PRINCIPAL STRESS IN COMBINED LOADING USING STRAIN ROSETTES

**Aim:** To determine Principal stress, principal strain, max shear stress, max shear strain using strain gauge rosettes.

**Apparatus required:**

1. Strain gauge rosette
2. Digital strain indicator
3. Solid shaft (Mild steel)

**Specification for strain gauge:**

| | |
|---|---|
| Type | : Rectangular rosette (Foil) |
| Gauge Resistance | : 120 ohms ± 0.5 |
| Gauge Factor | : 2 |
| Gauge Length | : 5mm |

**Theory:**

The mathematical analysis of stresses in complex components may not, in some cases, be practical or either not available or cumbersome and uneconomical investigations for confirmation of analytical formulations. Experimental stress analysis of strain measurement techniques has served on increasingly important role in aiding designers to produce not only efficient but economic designs. The accurate measurement of stresses strain and loads in components under working conditions is an essential requirement of successful engineering design. In particular location of peak stress values and stress concentration, and subsequently their reduction are removal by suitable design, as applications in every field of engineering.

The main techniques of experimental stress analyses which are in use today are:

1. Brittle Lacquers
2. Strain Gauges
3. Photo Elasticity
4. Photo Elastic coatings

**Strain Gauges:**

A strain gauge is strain transducer. It is device for measuring dimensional change on the surface of a structural member under test.

**Rosettes:**

Multiple grid or rosettes are a group of gauges bounded in the same supporting material in definite relative positions. Depending on the agreement of the grids we have rectangular, delta and T-delta rosettes. The gauges are to be aligned in principal directions. θ is the angle of reference measured positive in counter clockwise direction. The strain gauges can be arranged in combination to get three elemental rectangular rosettes or three element rectangular rosettes three element delta rosette or four elemental rectangular rosettes.

**Setup:**

The setup consists of L- bracket in which bottom plate is fixed rigidly on the table and vertical plate holds the specimen. One end of the specimen is rigidly fixed by means of screws. The end of the specimen is fixed with loading arm. Strain gauges are mounted on the specimen in the form of three elements rectangular rosettes. The strain gauge outputs are taken out through connectors. These outputs are connected to the corresponding channels of strain indicator. Strain indicator is provided with three independent displays for each gauge. Separate zero and calibration provision is made individually.

**Procedure:**

1. Make the necessary connections to the digital strain indicator from sensor. Adjust the indicator knob to zero.
2. Load the specimen with the aid of loading arm in steps.
3. Record the strain in micro strains by connecting corresponding strain gauges to the indicator with the help ob probes.
4. The three recording are recorded which indicates bending and torsional strains. (torsional- > two readings +ve and -ve)
5. Repeat the above procedure for different load in steps.
6. Compute the required parameters by using appropriate equations.
7. Finally draw the Mohr's circle to compare the obtained results.

**Observation:**

Material of the specimen: Mild steel

Diameter of the specimen, D =

Length of the shaft, =

Length of the torque arm, L =

Modulus of Elasticity, E = 210 GPa

Modulus of Rigidity, G = 70 GPa

Poison's Ratio, μ = 0.3

**Tabular Column:**

| Sl. No | Load in N | Strain indicator reading | | | Principal stress (MPa) | | Principal strain (μ strain) | | Max shear stress (MPa) | Max shear strain |
|---|---|---|---|---|---|---|---|---|---|---|
| | | $\varepsilon_A$ | $\varepsilon_B$ | $\varepsilon_C$ | $\sigma_1$ | $\sigma_2$ | $\varepsilon_1$ | $\varepsilon_2$ | $\tau_{max}$ | $\gamma_{max}$ |
| 1 | | | | | | | | | | |
| 2 | | | | | | | | | | |
| 3 | | | | | | | | | | |
| 4 | | | | | | | | | | |

**Rosette Analysis**

**Three Elements Rectangular Rosette Analysis:**

$\varepsilon_A = \varepsilon_{xx} \cos^2\theta_A + \varepsilon_{yy} \sin^2 \theta_A + \gamma_{xy} \sin\theta_A . \cos\theta_A$

$\varepsilon_B = \varepsilon_{xx} \cos^2\theta_B + \varepsilon_{yy} \sin^2 \theta_B + \gamma_{xy} \sin\theta_B . \cos\theta_B$

$\varepsilon_C = \varepsilon_{xx} \cos^2\theta_C + \varepsilon_{yy} \sin^2 \theta_C + \gamma_{xy} \sin\theta_C . \cos\theta_C$

Where $\varepsilon_{xx}$ – Strain along x - axis

$\varepsilon_{yy}$ – Strain along y - axis

$\gamma_{xy}$ – Strain along xy – plane

Normally, $\theta_A = 0^0$, $\theta_B = 45^0$, $\theta_C = 90^0$

When $\theta_A = 0^0$; $\varepsilon_A = \varepsilon_{xx} \cos^2\theta_A = \varepsilon_A = \varepsilon_{xx}$

$\theta_B = 45^0$; $\varepsilon_B = (\varepsilon_{xx} + \varepsilon_{yy} + \gamma_{xy}) / 2$

$\theta_C = 90^0$; $\varepsilon_C = \varepsilon_{yy}$

Principal strains $\varepsilon_{1,2}$ is given by

$$\varepsilon_{1,2} = \frac{\varepsilon_{xx} + \varepsilon_{yy}}{2} \pm \frac{1}{2}\sqrt{\left(\varepsilon_{xx} - \varepsilon_{yy}\right)^2 + \gamma_{xy}^2}$$

$$\varepsilon_{1,2} = \frac{\varepsilon_A + \varepsilon_C}{2} \pm \frac{1}{2}\sqrt{(\varepsilon_A - \varepsilon_C)^2 + (2\varepsilon_B - \varepsilon_A - \varepsilon_C)^2}$$

$\Upsilon_{xy} = \tau_{xy}/G$;

G- Rigidity modulus = 70 GPa for steel

$\Upsilon_{xy} = 2\varepsilon_B - \varepsilon_A - \varepsilon_C$

And the orientation is given by

$$\theta = \frac{1}{2}\tan^{-1}\left|\frac{\gamma_{xy}}{\varepsilon_{xx} - \varepsilon_{yy}}\right|$$

Principal stresses

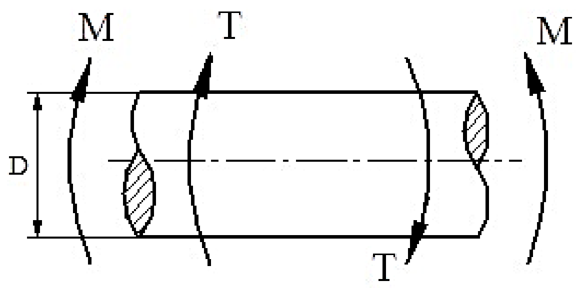
$$\sigma_1 = \frac{E}{1-\mu^2}(\varepsilon_1 + \mu\varepsilon_2)$$

$$\sigma_2 = \frac{E}{1-\mu^2}(\varepsilon_2 + \mu\varepsilon_1)$$

Where μ = poison's ratio = 0.3 for steel

**Analytical method:**

**Shaft subjected to combined bending and torsion**




Consider a shaft of diameter 'D' subjected to a moment 'M' and torque 'T'. Bending stress and shear stresses are maximum at extreme points. At these points

$$\sigma = \frac{M}{Z} = \frac{32M}{\pi D^3}$$

and shearing stress 'τ' is given by

$$\tau_{xy} = \frac{16T}{\pi D^3}$$

**Principal stresses**

$$\sigma_1 = \frac{16}{\pi}\left[\frac{M}{D^3} + \sqrt{\left(\frac{M}{D^3}\right)^2 + \left(\frac{T}{D^3}\right)^2}\right]$$

$$\sigma_2 = \frac{16}{\pi}\left[\frac{M}{D^3} - \sqrt{\left(\frac{M}{D^3}\right)^2 + \left(\frac{T}{D^3}\right)^2}\right]$$

and Max. Shear stress is given by

$$\tau_{max} = \frac{16}{\pi}\sqrt{\left(\frac{M}{D^3}\right)^2 + \left(\frac{T}{D^3}\right)^2}$$

Further, we know the stress - strain relationship and therefore, we use the following equations to calculate the principal strain in terms of principal stress by knowing the young's modulus (E)

$$\varepsilon_1 = \frac{1}{E}(\sigma_1 - \mu\sigma_2)$$

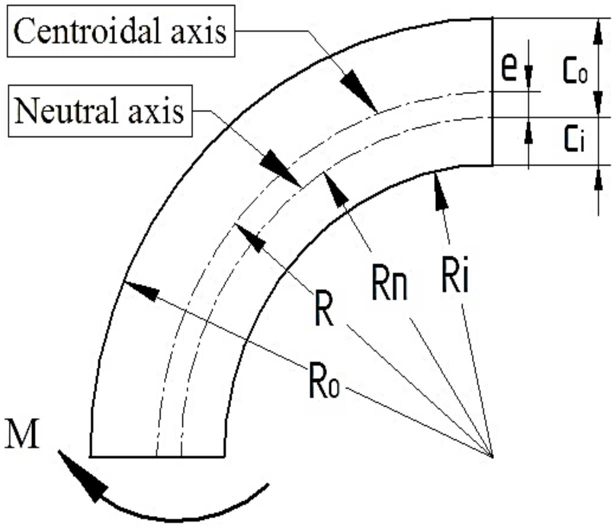
$$\varepsilon_2 = \frac{1}{E}(\sigma_2 - \mu\sigma_1)$$

Where μ = poison's ratio = 0.3 for steel and E = 210GPa

Experiment No. 07

## STRESSES DEVELOPED IN CURVED BEAM

**Aim:** To determine the stresses developed in curved beam.




**Apparatus Required:**

1. Test specimen (bonded with strain gauge).
2. Load cell.
3. Load indicator.
4. Strain indicator.
5. Fixture.

**Theory:**

A curved beam is defined as a beam in which the neutral axis in the unloaded condition is curved instead of straight. Bending stresses in curved beams do not follow the same linear variation as straight beams because of the variation in arc length. There is linear stress variation in a straight beam and the hyperbolic stress distribution in a curved beam.

A load cell is an electronic device (transducer) that is used to convert a force into an electrical signal.

A strain gauge is a device used to measure the strain of an object. The most common type of strain gauge consists of an insulating flexible backing which supports a metallic foil pattern. The gauge is attached to the object by a suitable adhesive, such as cyanoacrylate. As the object is deformed, the foil is deformed, causing its electrical resistance to change. This resistance change, usually measured using a Wheatstone bridge, is related to the strain by the quantity known as the gauge factor.

Gauge factor is defined as the ratio of fractional change in electrical resistance to the fractional change in length (strain):

$$GF = \frac{\Delta R/R}{\Delta L/L} = \frac{\Delta R/R}{\varepsilon}$$

**Procedure:**

1. Calibration of the load indicator.

a) Connect the load cell with the load indicator.
b) Switch on the load indicator.
c) Set, zero by pressing the button (red).

d) Display shows zero

e) Put standard dead weight (at least 1/4th of the load cell capacity) on the load cell. Maximum load cell capacity is 200 kg.

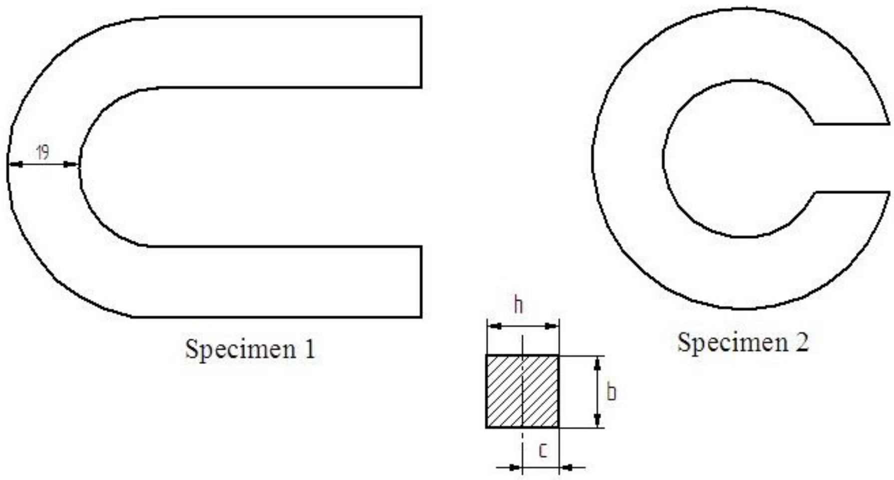
f) If the load applied is 80 kg (say, weight of a student), the load indicator displays it as 79 then -press the first key on the load indicator. On successive pressing of the 1st key the displays are bd, pt, o, op, dp.

g) Suppose the display shows a number (say 1900) then increase this value by pressing the 2nd key and if the reduction is required then press the 3rd key.

h) Now press the 1st key and if the load shown is same to the dead weight then STORE the data else repeat the process.

i) To store the data, press the 4th key,

2. Fix the specimen with the help of fixture to the load cell.
3. Clamp the load cell with the base of equipment.
4. Connect the strain gauge to the strain indicator.
5. Select '2 arm' in the strain indicator.
6. Apply the load on the specimen by the screw.
7. Load indicator when crosses the value: or 50 kg then start taking the readings on the strain gauge indicator.

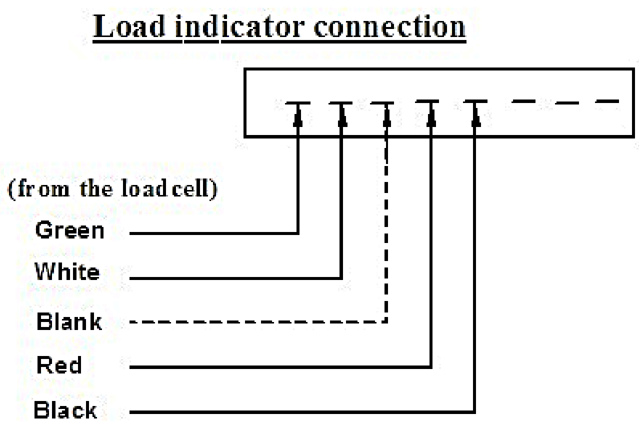


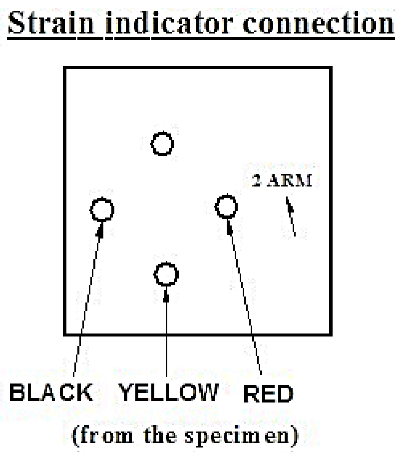

Specimen 1

Specimen 2

Cross section of the specimen 1 & 2

| **Specimen 1** | **Specimen 2** |
|---|---|
| $R_0$ = 40 mm | $R_0$ = 38 mm |
| R = 30.5 mm | R = 30.5 mm |
| Ri = 21 mm | Ri = 21 mm |
| b = 19 mm | b = 17 mm |
| h = 19 mm | h = 17 mm |
| c = 9.5 mm | c = 9.5 mm |




**Tabular column:**

| Sl. No. | Load applied in kg | Strain indicator reading in µ strain | Theoretical µ strain |
|---|---|---|---|
| 1 | 50 | | |
| 2 | 75 | | |
| 3 | 100 | | |
| 4 | 125 | | |
| 5 | 150 | | |

**Calculation:**

$$e = R - R_n = R - \frac{h}{\log_e \frac{R+C}{R-C}}$$

$C_i = R_n - R_i =$

$C_0 = R_0 - R_n =$

Let the load applied be W newton

Therefore bending moment,

M = W x (Distance between the point of application of load and the centroidal axis)

At the outer fiber the maximum tensile stress due to bending,

$$\sigma_0 = \frac{MC_0}{AeR_0}$$

At the inner fiber the maximum compressive stress due to bending,

$$\sigma_i = -\frac{MC_i}{AeR_i}$$

Direct stress, $\sigma_d = \frac{F}{A}$

Total stress = $(\sigma_0 + \sigma_d)$ or $(\sigma_i + \sigma_d)$

$\sigma$ = E x $\varepsilon$ ε is the strain

Find ε (Theoretically) = $\frac{\sigma}{E}$

**Result:**

1. The value of stress = _ _ _ _ _ N/mm$^2$
2. The value of strain = _ _ _ _ _